White Paper WP14

Power-over-Ethernet Plus

An Overview

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TABLE OF CONTENTS

FIGURES AND TABLES

INTRODUCTION

Power over Ethernet (PoE) is a standardized technology that allows transmission of power along with the data over existing Ethernet cables. The technology can greatly simplify the wiring and deployment of networked appliances in a home and office environment.

Power over Ethernet is standardized by the IEEE® 802.3 committee. The first generation of PoE standard is IEEE 802.3af – 2003, which defines the maximum device input power at 13W. Initial deployments of PoE technology were driven by the need for Voice-Over-IP (VoIP) Telephony systems and WiFi Networking in the enterprise environment. As PoE has gained popularity, there has been a demand for even more network-powered appliances. However, many critical applications which could benefit from PoE, such as PTZ IP security cameras and access controllers, RFID readers, thin-client computers, multi-antenna based Wireless Access Points, etc., require more than 13W of input power.

To facilitate the higher power requirements, the IEEE committee is working to standardize the next advancement of PoE, the IEEE 802.3at standard, also referred to as PoE Plus (PoE+). The PoE+ standard will allow for the delivery of over 25W of input power. With 802.3at, a completely new class of devices can be powered directly via the network interface. These include RFID terminals, pan-tilt-zoom security cameras, 802.11n wireless access points, video phones, laptops, thin-client computers and point of sale terminals.

PoE products and services are now available worldwide and their benefits are the driving factors for the growth of this technology.

THE IEEE® 802.3AT (PoE PLUS) STANDARD

STANDARD OBJECTIVES

In 2005, the IEEE formulated a new group that is driving the next standard for PoE. The standard will be called the IEEE® 802.3at (also known as PoE Plus). Key objectives of this standard are as follows:

- PoE Plus will enhance 802.3af and work within its framework – there will be no new clause.
- The target infrastructure for PoE Plus will be ISO/IEC 11801-1995 Class D/ANSI/TIA/EIA-568.B-2 category 5 (or better) systems with a DC loop resistance no greater than 25 Ohms. Further the new standard will not cause a safety issue for a legacy installation with equipment conforming to ISO/IEC 60950.
- IEEE STD 802.3 will continue to comply with the limited power source and SELV requirements as defined in ISO/IEC 60950.
- The PoE Plus PSE shall operate in modes compatible with the existing requirements of IEEE® STD 802.3af as well as enhanced modes.
- The enhanced standard will provide the maximum power to the PD as allowed within practical limits.
- PoE Plus shall support a minimum of 24 Watts of power at the PD PI (power interface).
- PoE Plus PDs, which require a PoE Plus PSE, shall provide the user an active indication when connected to a legacy 802.3af PSE. This indication is in addition to any optional management indication that may be provided.
- The standard shall not preclude the ability to meet FCC/CISPR/EN Class A, Class B, Performance Criteria A and Performance Criteria B with data for all supported PHYs.
- Research potential extension of power classification to support PoE Plus modes.

- PoE Plus will vigorously pursue supporting the operation of midspan PSEs for 1000BASE-T.
- That IEEE® 802.3af power over the MDI isolation requirements be revisited as part of the PoE Plus work.
- PoE Plus PDs within the power range of 802.3af will work properly with 802.3af PSEs.
- PD Operation based on PSE

Table 1 - PD and PSE Interoperability

	IEEE Std 802.3af PSE	PoE Plus PSE
IEEE Std 802.3af PD	Operates	Operates
PoE Plus PD <12.95W	Operates	Operates [1]
PoE Plus PD >12.95W	PD shall provide user active indication	Operates [1]

[1] Operates with extended power classification

STATUS & MILESTONES OF IEEE 802.3AT

- Nov-2004: Study Group Created
- Jul-2005: IEEE 802.3 recommended creation of Task Force
- Sep-2005: IEEE 802.3at Power over Ethernet Enhancements Task Force Created
- Nov-2007: Draft 1.0 Released
- Mar-2008: Draft 3.0 Released
- July-2008: Draft 3.1 Released; Standard review starts at IEEE 802.3 level
- Nov-2008: Plenary meeting, Final Standard at IEEE 802.3 (expected)
- 2H 2009: Expected Completion of work

BENEFITS OF PoE

First generation of PoE benefits are now well known to the industry. Some of these include:

- ***Cost effectiveness:*** Since PoE allows transmission of power down the same cable as data, the overall cost of deployment is reduced by not having to connect to or install a dedicated AC outlet.
- ***Safety:*** PoE eliminates the need for high-voltage mains, since power is delivered using direct current at 48V.
- ***Reliability:*** PoE is managed from a centralized UPS. Therefore, in the event of power failure, the PoE system continues to provide power to the PD.
- ***Mobility:*** Since the PD does not need to be near an AC outlet, systems like security cameras and wireless LAN access nodes can be deployed in more suitable areas, such as office ceilings.
- ***Control:*** IT managers can take advantage of having one central location for power supply and data transmission management. They can also monitor and manage power deployment using network management protocols such as SNMP. This leads to improved energy efficiency, lower electrical costs, enhanced troubleshooting capabilities, and improved security. For remote applications, this allows disabling of IP devices for increased network security.
- ***Standards based:*** System vendors can offer interoperable solutions at a competitive price to end users, all based on IEEE® 802.3af and IEEE® 802.3at.

WHY PoE PLUS

IT managers have gone through their first phase of PoE deployments in many environments and realized the substantial benefits of PoE-based appliances. Hence there is a strong demand to bring PoE to a wide variety of new applications, many of which require more power than the 13W provisioned by the current standard.

Overall power management is crudely built into PoE clients today, via PoE power classification, but this is a limited and static solution. It is not aligned with IT managers' desire for a dynamic, fine-grain, end-to-end power management environment that meets enterprise energy conservation goals. PCs, servers, and even traditional Ethernet (e.g. IEEE's Energy Efficient Ethernet initiative) are all being unified today under the power management umbrella, so extending similar practices to PoE devices would appear to be a prudent course of action.

The new PoE Plus standard ties in sophisticated Enterprise Power Management capabilities, along with the delivery of higher power, while still maintaining backward compatibility with existing standards and deployments.

- ***Higher Power Delivery:*** PoE Plus provisions 25.5W power to the Powered Device (PD), enabling the integration of many new IP appliances in a managed power network. The rapidly-growing market segments for high power PoE Plus application include PTZ surveillance cameras, 802.11n enterprise AP routers, video conference IP Phones, PoE-ready thin clients, etc.
- ***PoE as Enterprise Power Management Tool:*** Power is a precious commodity in the modern "Green" enterprise. Prudent management and conservation are essential requirements. The PoE Plus standard provides means and methods for intelligent and dynamic allocation of power. The standard extends the vendor-neutral Ethernet Layer 2 communication protocol, called Link Layer Discovery Protocol (LLDP), for use in end-to-end power management. This allows PDs to dynamically communicate their power requirements so that the IT managers controlling the PSEs can implement enterprise-appropriate energy policies.

- ***Backwards Compatibility:*** PoE Plus is backwards compatible with the current 802.3af standard. This ensures smooth transition of the industry from current PoE deployments to PoE Plus deployments without fork-lift infrastructure upgrades. PoE and PoE Plus appliances can co-exist in the enterprise and the PoE Plus deployment can start based on application needs.

In light of the tremendous benefits of migrating from PoE to PoE Plus, Akros Silicon has developed a Universal PD Reference Design to help the customers' seamlessly migrate between the different power schemes. Please see list of references and Akros Silicon website for detailed application note.

THE IEEE 802.3AF VS. IEEE 802.3AT AT A GLANCE

The following table shows a comparison of the 802.3af and 802.3at standards, highlighting the key system-level differences. The following definitions are transcribed directly from the IEEE802.3at Standards Draft:

- ***Type 1 PD:*** A PD that advertises a power draw less than or equal to 12.95W (at the PD).
- ***Type 1 PSE:*** A PSE that is designed to support a Type 1 PD.
- ***Type 2 PD:*** A PD that advertises a power draw greater than 12.95W (at the PD).
- ***Type 2 PSE:*** A PSE that is designed to support either a Type 1 or a Type 2 PD.

Table 2 - PoE vs. PoE+ Differences

Features	PoE (802.3af)	PoE Plus (802.3at)
Cable Requirement	Category 3 or better	Type 1: Category 3 or better Type 2: Category 5 or better, with DC loop resistance < 25Ω
Cable Current (A) PSE & PD	0.35 A	Type 1: 0.35 A Type 2: 0.6 A
PSE Output Voltage (Vdc)	44 - 57 Vdc	Type 1: 44 – 57 Vdc Type 2: 50 – 57 Vdc
PD Input Voltage (Vdc)	37 - 57 Vdc	Type 1: 37 – 57 Vdc Type 2: 42.5 – 57 Vdc
Maximum PD Wattage (W)	Class 0, 3: 12.95 W Class 1: 3.84 W Class 2: 6.49 W Class 4: Unused	Type 1: Class 0, 3: 12.95 W Class 1: 3.84 W Class 2: 6.49 W Type 2: Class 4: 25.5 W
Classification Requirements	1-Event Classification is optional for PSEs and Mandatory for PDs	Type 1: 1-Event Classification is optional for PSEs and mandatory for PDs Type 2: PSEs can deliver 2-Event Classification only, LLDP only, or 2-Event Classification and LLDP PDs must respond to 2-Event Classification AND LLDP

POE PLUS HANDSHAKE MECHANISM

One major implementation difference between IEEE 802.3af and IEEE 802.3at, other than their maximum power capability is the classification signal. Classification is a handshake mechanism that allows the PSE and PD to communicate each others' power requirements and capabilities. By employing this method, designers can create systems that minimize power usage, allowing more devices to be supported on an Ethernet network.

In the current 802.3af PoE environment, when a PSE senses a PD on a port, it inserts a short pulse on the pairs to measure how much power the PD needs. The PD then responds to the pulse by briefly drawing a predetermined amount of current. The amount of current indicates the "class" of the PD – which essentially translates to how much power the PD equipment intends to draw. There are 5 classes, defined as 0, 1, 2, 3 and 4. The table below shows the PD power rating for each class, and the current provided by the PD in response to the PSE's Classification Pulse. Refer to Figure 1 for electrical signaling details.

Table 3 - PD Class vs. Advertised Power

Class	Power (W)	I_{CLASS} (mA)
0	0.44 - 12.95	0-4 mA
1	0.44 - 3.84	9-12 mA
2	3.84 - 6.49	17-20 mA
3	6.49 - 12.95	26-30 mA
4	12.96 - 25.5	36-44 mA

As outlined in Table 2, the standard allows for two approaches for communicating PD-PSE capabilities to each other – a hardware-based method, referred to as "Two-Event Classification", and a software-based method utilizing LLDP protocol. Below, sections discuss the details of the Two-Event Classification method and the benefits of using the hardware-based handshake over a software-based method.

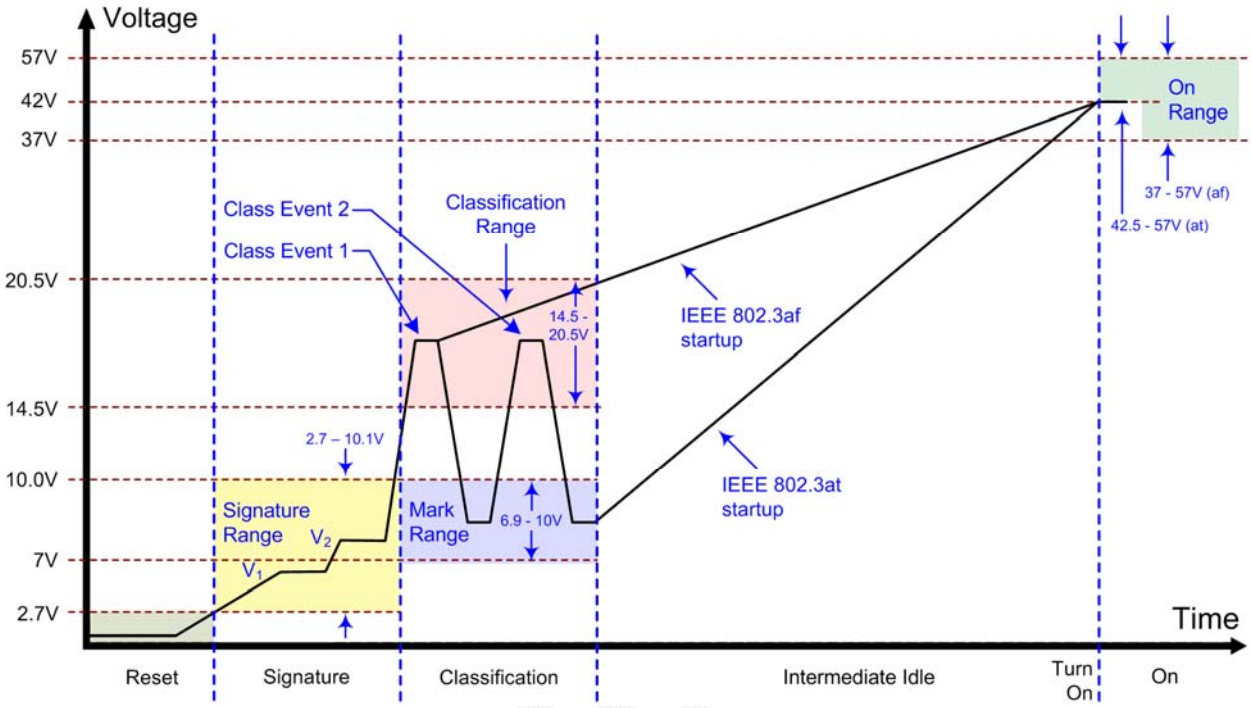
PHYSICAL LAYER HANDSHAKE – TWO-EVENT CLASSIFICATION

A standard Type 1 PSE supplies only 1-event classification, regardless of the class setting of the PD. However, a Type 2 PSE will detect the classification setting from the PD and determine whether a 1-event or 2-event classification signal needs to be applied. If PD classification is set between 0–3 (i.e. Type 1 PD), the PSE will then apply a 1-event classification signal, internally recognizing the PD as Type 1. If the PD classification is set to 4, the PSE will recognize the PD as a Type 2 PD. It will then apply a 2-event classification, to indicate to the PD that it is a talking to a Type 2 PSE and that more than 12.95W of power is available. Hence, 1-event or 2-event classification signaling is used by the PD to detect if it is connected to a Type 1 or Type 2 PSE, respectively. When the Type 2 PD responds correctly to the 2-event classification signals, the PSE validates that it's connected to a Type 2 PD and hence can go into full 802.3at power mode. Electrical signaling details are discussed in the next section.

For safety reasons, the standard defines that the PoE Plus PSE will startup only in the default 802.3af power mode (13W) until it has positively identified a Type 2 PD on the other end. Once 2-event classification signaling has confirmed the existence of a Type 2 PD, the PSE will step up to full 802.3at power mode.

802.3AT TYPICAL POWER-ON WAVEFORM

Figure 1 - 802.3at Typical Power-On Waveform



1. Voltages V1 and V2 are applied by the PSE to extract a signature value.

2. The PSE takes current/impedance readings during Class/Mark Events to determine the class of the PD. At this time, the PD presents a load current determined by the resistance connected to the RCLASS pin.

3. After the PSE measures the PD load current, if it is a high-power PSE, it presents a mark voltage (6.9-10V), followed by a second classification voltage. The PD responds by presenting a load current as determined by the resistor on the RCLASS pin. After the PSE measures the PD load current the second time and determines that is can deliver the requested power, it moves into the On state by raising the voltage to approximately 42V.

Note: During the classification of a Type 2 PD, the PSE outputs a sequence of voltage signals (Class 1, Mark 1, Class 2, Mark 2) within the specific timing requirement. The PD has to respond within the limit range of voltage/current/impedance for each event according to section 33.3.5 PD Classifications of 802.3at standard.

TYPE 2 PSE INDICATOR – ATDETECT

Once a Type 2 PD has been positively identified by a Type 2 PSE (using 2-event classification), the PD can signal to its downstream electronics/microcontroller the availability of full 802.3at power. Akros Silicon's 802.3at PD controllers refer to this functionality as "ATDETECT".

When a Type 2 PD links with a Type 1 PSE, ATDETECT will indicate to the system that only 13W of power can be supplied. If this PD links to a Type 2 PSE, ATDETECT will indicate that the full 25.5W power is available.

System designers can utilize the ATDETECT indicator in the design phase for self-configuration of an IP appliance based on the available power from the network. This will allow designers to build advanced systems that can still provide basic functionality when connected to an 802.3af Type 1 PSE, and full functionality when connected to an 802.3at Type 2 PSE.

Some examples of self-configuration at boot-up include:

- An 802.11n multi-antenna, multi-radio access point can have a default configuration for single-radio/antenna, but can be configured to a higher-bandwidth, multi-radio/antenna system when linked to an AT PSE.
- A thin-client computer can provide basic graphics and lower-speed communication in AF mode, but can provide higher-end graphics and bandwidth capability when linked to an AT PSE.
- A PTZ camera can offer basic camera functionality and digital zooming in AF mode, but provide fully-motorized enhanced capabilities when AT power is available.

PHYSICAL LAYER (HARDWARE) VS. LLDP (SOFTWARE) HANDSHAKE

The standard allows for two means of communicating PD-PSE capabilities to each other – a hardware-based Two-Event Classification method, and a software-based method utilizing LLDP protocol. The PD must support both methods, while the PSE can support either one or both.

As mentioned above, a Type 2 PSE enables full AT power only after positive, bi-directional identification of AT-level PD capability is established. Below are the key system differences between hardware and software implementations:

- Physical-layer handshaking is faster, since it's done during the power-up sequence. Therefore, immediately upon boot-up, the system will come up in the correct power configuration, without relying on any data communication. For software handshaking, the system must power up, initialize its microcontroller, establish the Ethernet link, and then go through a bi-directional packet exchange sequence – a process that can take substantial time.
- Hardware implementation is simple and error-resistant. Since power configuration is a fundamental system parameter, it's more robust to rely on fixed hardware recognition rather than software. Testing and validating a software implementation for all possible scenarios can end up being a daunting task.

In a test implementation, physical-layer handshaking enabled system power configuration in less than two seconds, whereas software LLDP implementation and recognition took nearly twenty seconds. In an environment that demands instantaneous availability of services, the time required to achieve the correct power setting can be critical.

End users are conditioned via legacy products that two seconds is an acceptable time for a 'simple' device (e.g. VoIP) to begin working, but may impatiently unplug something as being non-functional if it does not begin operating as expected for a much longer time. A twenty-second power-up delay may result in unnecessary service calls and/or repair tickets.

ENTERPRISE POWER MANAGEMENT WITH PoE PLUS

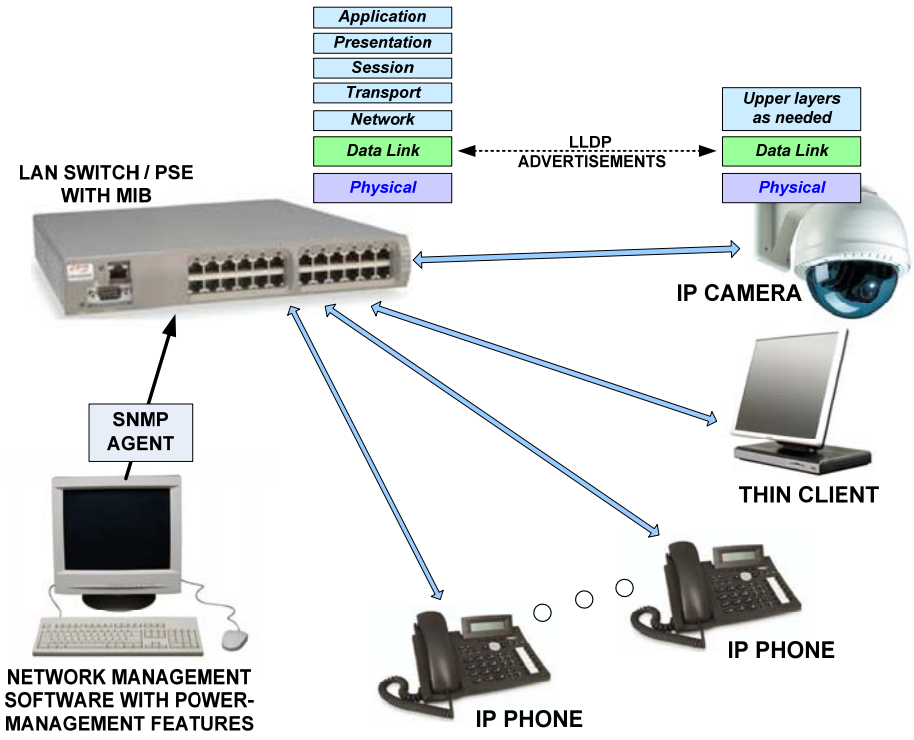
One of the most exciting new enhancements with PoE Plus is the ability to control power distribution in much finer detail than with the existing standard. PoE Plus addresses the growing demand for enterprise "Green Power" initiatives – more efficient use and intelligent allocation of power, as well as a reduction in the overall energy footprint.

An 802.3af PSE simply identifies a PD's class and provides the maximum power allowable under the class definition. However, once an 802.3at system is powered up, an 802.3at PSE will be able to use Layer 2 software communication (LLDP, refer to Appendix A) to query each PD to determine peak and average power requirements, dynamically. This new capability will allow designers building PoE systems to budget power and match total system power capabilities to system load requirements much more closely.

For example, in the enterprise, VoIP phones do not require steady availability of the 6.5Watts or 13Watts that are allocated to them via initial PSE/PD classification. They can be reduced to a much lower standby power and quickly ramp up to their active power level upon the initiation of a call or other wake-up event. The PSE can dynamically reallocate power to the ports that need active power. For example, a PSE supporting 50 VoIP phones does not have to be built to support simultaneous full power usage of all 50 phones. If the PSE can reallocate power based on immediate need, it can reduce overall power supply requirements by half to a quarter, depending on the statistical usage pattern of the phones in that environment.

Similarly, IP cameras working in low light, generating high-definition IP video streams of rapidly-moving objects might only require its maximum 25.5W allocation during a midnight alarm condition, likely when the VoIP phone usage is minimal. So power to the VoIP ports can be reallocated to the IP camera ports after business hours. Figure 2 below shows an example of implementation on an enterprise network. Please see Appendix A for more detailed description of the LLDP mechanism.

Figure 2 - Enterprise Power Management via LLDP Advertisements



POE PLUS AS A COMPETITIVE BENEFIT

With intelligent power management, servers and PSEs can now be used to monitor PD status and power usage profiles. Therefore, IT managers can continuously analyze and adjust power usage policies to drive continuous improvements. Since these policies are implemented at the software level on both the PD and PSE ends, they can be field upgraded with firmware loads without changing the physical hardware – providing continuous cost savings.

System vendors developing PoE Plus equipment with field upgrade capabilities can immediately benefit from the greening of the enterprise by offering PoE+ capability as a competitive benefit in their product line. Transitioning IP appliances to PoE+ capability has excellent Return on Investment (ROI), even in the short term.

AKROS' UNIVERSAL REFERENCE DESIGN FOR PoE PLUS MIGRATION TODAY

Standard IEEE 802.3af PD designs are well adopted in today's market. Higher power can be provisioned via the upcoming IEEE 802.3at standard. However, in the interim, many customers have been designing semi-proprietary solutions to work with PSEs/mid-spans that deliver up to 30Watts of power using the IEEE 802.3af-based handshake mechanism. Such a requirement change often leads to a complete redesign or platform change that demands significant engineering resources. This results in higher development costs, longer development cycles, potentially missed production windows, and (most importantly) an increased risk of introducing new design bugs.

In light of the tremendous benefits of migrating from PoE to PoE Plus, Akros Silicon has developed a Universal PD Reference Design to help the customer migrate between the different power schemes. Akros Silicon's AS1135-based Universal PD reference design minimizes the component changes to only three (3) components, with no additional design effort, when switching from the 13W 802.3af to the 25W/30W 802.3at/af standard, or vice-versa. All available power schemes using this universal reference design are mapped to the same pinout, PCB layout and solution size – making design, development, validation and the production process extremely simple. Please see list of references for application note information detailing the universal reference design.

The AS1135 is the only IEEE Draft 802.3at/D3.1 pre-standard PD/PWM production-ready solution on the market (as of August 2008). The AS1135 offers the designer an easy-to-design, lower-BOM cost, and smaller-area solution for today's 802.3af PoE standard and is designed with the next-generation 802.3at PoE+ pre-standard in mind.

SUMMARY

Today, Power over Ethernet (PoE) has been widely adopted in many applications, such as IP Phones, Wireless APs, IP Surveillance Cameras, RFID readers, etc. It is an exciting technology that allows users to take advantage of cost and power savings, increases flexibility and improves reliability by combining delivery of data and power on the same network.

The new PoE Plus standard ties in sophisticated Enterprise Power Management capabilities along with delivery of higher power (up to 25.5W), while maintaining backwards compatibility with existing standards and deployments. Higher power enables a gamut of new applications and IP appliances to benefit from growing PoE infrastructure and usage. The dynamic and intelligent power allocation and management capabilities built into the PoE Plus standards will empower IT managers to meet enterprise energy savings and conservation goals, delivering on the "Green Power" enterprise initiatives.

Key hardware aspects of the IEEE 802.3at standard have been finalized, such that system designers can begin implementation and deployment of this technology right away. System vendors developing PoE Plus equipment with field upgrade capabilities can immediately benefit from the greening of the enterprise and can use the PoE+ capability as a competitive advantage in their product line. Transitioning IP appliances to PoE+ capability has excellent Return on Investment (ROI), even in the short term.

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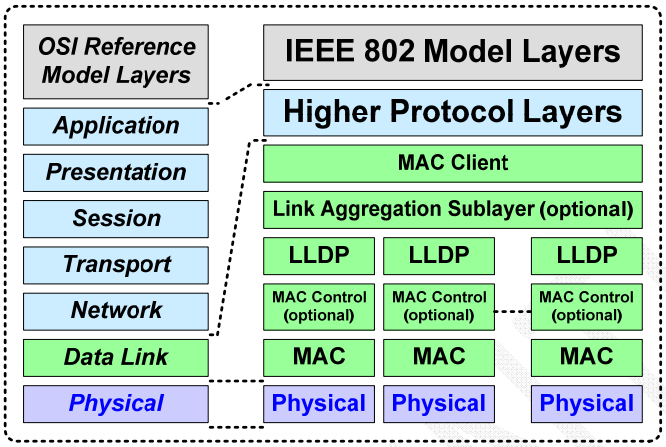
3. IEEE P802.3at DTE Power Enhancements Task Force Objectives http://www.ieee802.org/3/at/objectives.html
4. Akros Silicon White Paper: Power-over-Ethernet Overview, Rev 2.0, May 2007
5. Akros Silicon Application Note: AN024 – AS1135 Universal PD Reference Design, Rev 1.0, July 2008
6. IEEE 802.1AB – Station and Media Access Control Connectivity Discovery website: http://ieee802.org/1/pages/802.1ab.html

APPENDIX A - LINK LAYER DISCOVERY PROTOCOL (802.1AB)

Link Layer Discovery Protocol ("LLDP") is a vendor-neutral neighbor-discovery protocol that allows Ethernet devices to identify and map other devices on a network. This is defined in the IEEE 802.1AB standard. Figure 3 below shows where LLDP resides in the IEEE 802 Network Model Layers. LLDP is a data-link layer protocol operating above the MAC service layer, and hence can be used in any networking device that implements a MAC service.

Figure 3 - Link Layer Discovery Protocol Architecture



The 802.1AB LLDP standard defines the method for each Ethernet device to 'advertise' its identification parameters to all other devices on the network, as well as receive and store similar 'advertisement data blocks' from other devices. This neighbor-hood device information is stored in IEEE defined Management Information Bases (MIBs) database, that is accessible to the network management software via SNMP (Simple Network Management Protocol).

Data block advertisements always contain the device's chassis ID and port ID, and will usually also provide the system name, description and capabilities – through information elements called TLVs (Type, Length, Value). The PoE Plus standard is defining PoE and Network Power Management specific TLVs for use via LLDP.

Advertisement data blocks are typically broadcast by each device every 30 seconds. Devices also pass along all previously-received advertisements from their neighbors, so that network management software can know what devices are operating on each of the network segments in the system. Each device will typically retain the received advertisement data block from a peer for about 2 minutes before discarding it. This assures that each device on the network always contains a list of current advertisement data blocks from every device that communicates with it.

The PoE Plus standard makes use of this pre-defined LLDP mechanism to dynamically advertise power requirements for each client. This enables the switch running network management software to dynamically manage power between devices and ports, and implement power management strategies as suitable for the enterprise.

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